

Estimating Performance and Costs of
Retrofit SO₂ and NO_x Controls for
Acid Rain Abatement

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16. ABSTRACT The paper gives results from an ongoing National Acid Precipitation Assessment Program (NAPAP) to significantly improve engineering cost estimates currently being used to evaluate the economic effects of applying SO ₂ and NO _x controls to existing coal-fired utility boilers. Initially, procedures were developed to: select plants with boilers representative of the population, conduct plant visits and collect site-specific data, develop boiler/control-specific retrofit difficulty factors, and develop boiler/plant-specific cost and performance estimates for the SO ₂ and NO _x controls selected for evaluation. Eleven commercial and developmental SO ₂ and NO _x control technologies were selected for inclusion in the program. Of 30 "top 200" plants selected for detailed study, 12 have been visited. Based on results from these 12 plants, simplified procedures have been developed and used to evaluate about 50 of the remaining top 200 plants.		13. TYPE OF REPORT AND PERIOD COVERED Published paper; 11/85-1/88	
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ESTIMATING PERFORMANCE AND COSTS OF RETROFIT SO₂ AND NO_x CONTROLS FOR ACID RAIN ABATEMENT

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INTRODUCTION

One of the responsibilities of the National Acid Precipitation Assessment Program (NAPAP) is to develop cost and performance information on various methods for reducing the emissions of acid rain precursors. This paper presents results from an ongoing program conducted under NAPAP by the U.S. EPA's Air and Energy Engineering Research Laboratory. The objective of this research program is to significantly improve engineering cost estimates currently being used to evaluate the economic effects of applying SO₂ and NO_x controls to existing coal-fired utility boilers.

In the initial phase of the program, procedures were developed: to select plants with boilers representative of the population, to conduct plant visits and collect site-specific data, to develop boiler/control-specific retrofit difficulty factors, and to develop boiler/plant-specific cost and performance estimates for the SO₂ and NO_x controls selected for evaluation. The commercial and developmental SO₂ and NO_x control technologies selected for inclusion in the program are listed in Table I.

TABLE I. EMISSION CONTROL TECHNIQUES SELECTED

Control Technique	Species Controlled	
	SO ₂	NO _x
Lime/limestone (L/LS) flue gas desulfurization (FGD)	X	
Additive enhanced L/LS FGD	X	
Lime spray drying (LSD) FGD	X	
Physical coal cleaning (PCC)	X	
Coal switching and blending (CS/B)	X	
Low-NO _x combustion (LNC)		X
Selective catalytic reduction (SCR)		X
Furnace sorbent injection w/humidification (LIMB)	X	
Duct sorbent injection	X	
Natural gas reburning (NGR)	X	X
Fluidized bed combustion (FBC) repowering	X	X

Thirty plants which appeared to be representative of the "top 200" SO₂-emitting plants (based on 1980 emissions) were preliminarily selected for detailed study. At this point in the program, 12 of these plants have been visited: 5 in Ohio and 7 in Kentucky and the Tennessee Valley Authority (TVA) system (which includes Tennessee and portions of Alabama and Kentucky). Capital and annual cost estimates were developed for applying the control technologies to the boilers of each plant. In addition, the performance of each technology at each boiler was estimated. Based on the results from these 12 plants, simplified procedures have been developed and used to evaluate about 50 of the remaining top 200 plants.

PLANT SELECTION FOR DETAILED STUDY

Boilers in the top 200 SO₂-emitting plants were categorized by generating capacity, coal percent sulfur, firing type, age, and capacity factor. Plants in the top 200 population were ranked according to their diversity, then the boiler categories represented by the 30 highest-scoring plants were evaluated to see if these plants represented a proportional sample of the entire top 200 population. Plants near the bottom of the list of 30, whose boilers caused categories to be over- or underrepresented, were replaced by plants which improved the representativeness of the sample. The 12 plants selected for Ohio, Kentucky, and the TVA system and their characteristics are listed in Table II.

COST/PERFORMANCE MODELS

Many of the performance predictions and most of the cost estimates were developed using computer-based simulation models. A number of mainframe and personal-computer-based models were evaluated prior to the selection of those to be used. The Integrated Air Pollution Control Systems (IAPCS) model¹, because of its versatility, has become the "workhorse" model under this study. The IAPCS model has been upgraded to include most of the technologies being applied in this program (see Table I).

DATA GATHERING

Prior to evaluating each plant, a plant "profile" is completed to the extent possible using sources of public information, beginning with Department of Energy (DOE) Energy Information Agency (EIA) Form 767. The plant profile is designed to include most of the information and data needed for the performance/cost analyses, with the exception of plot plans (or aerial photographs) and boiler drawings, which were obtained (when available) during the plant visits. In the 12 detailed plant studies the preliminary plant profiles were typically sent to the utility for review and comment prior to the plant visit; the profile was completed using information obtained during the visit. In the simplified procedures, plot plans, aerial photographs, and utility trade magazine boiler data are used, along with the Form 767 data, to characterize the plant.

TABLE II. PLANT/BOILER CHARACTERISTICS FOR 12 OHIO, KENTUCKY, AND TVA PLANTS

Plant Name	Generating Unit No.	Net Dependable Generating Capacity, Per Unit, MW	Age, yr	Capacity Factor, percent	Coal Sulfur, percent	Firing Type
Burger (OH)	1-2	60	40-43	29-30	3.4	Roof
	3	90	37	31	3.4	Roof
	4-5	150	32	38-56	3.4	Wall
Conesville (OH)	1-2	125	28-30	32-36	2.9	Cyclone
	3	165	25	37	2.9	Wall
	4	720	14	58	2.9	Tangential
	5-6	375	9-11	45-48	4.1	Tangential
Muskingum River (OH)	1-2	205	33-34	63	4.4	Wall (wet bottom)
	3-4	215	29-30	55	4.4	Cyclone
	5	585	19	61	4.4	Wall
Sammis (OH)	1-4	180	25-28	44-57	0.9	Wall
	5	300	20	53	2.4	Wall
	6-7	600	16-18	44-51	2.4	Wall
Stuart (OH)	1-4	559	13-17	56-66	1.2	Wall (cell burner)
Brown (KY)	1	100	30	50	1.9	Wall
	2	156	24	65	1.9	Tangential
	3	410	16	65	1.9	Tangential
Elmer Smith (KY)	1	151	23	30	2.9	Cyclone
	2	265	13	50	2.9	Tangential
Big Sandy (KY)	1	260	24	63	1.2	Wall
	2	800	18	63	1.2	Wall
Colbert (TVA)	1-4	200	32	50	2.3	Wall
	5	550	22	50	2.3	Wall
Johnsonville (TVA)	1-4	125	35-36	39	1.7	Tangential
	5-6	147	34-35	30	1.7	Tangential
	7-10	173	28-29	41	1.7	Wall
Cumberland (TVA)	1-2	1300	14	60	2.9	Wall
Paradise (TVA)	1-2	704	24	30	2.9	Cyclone
	3	1150	17	30	2.9	Cyclone

PERFORMANCE/COST ESTIMATING RESULTS

Using the data and information obtained on each plant, retrofit factors were developed for those technologies which are typically based on the cost of new installations (e.g., FGD, LSD, SCR). These factors are estimated using site-specific location and difficulty factors as well as "cost adders" which involve items not normally included in new plant costs, such as a new chimney or demolition/replacement of existing buildings. The procedures used to develop FGD retrofit factors, which have been used in numerous FGD cost estimating studies by EPA and others, were developed by the Electric Power Research Institute (EPRI)². Application of these procedures to evaluate FGD applications in this study was described in a previous paper³.

A similar approach was used for the remaining "new-plant-basis" technologies. Using the retrofit factors and the new plant costs, cost estimates were developed for applying these technologies, when feasible, on a (generating) unit-by-unit basis throughout each plant. Similarly, technologies for which retrofit costs are normally calculated directly (e.g., LIMB) were estimated for each plant. The economic premises for the cost estimates were based on the EPRI Technical Assessment Guide (TAG)⁴.

Performance/cost estimates for applying FGD to the five Ohio plants are shown in Figure 1. In the figure the levelized annual revenue requirements, in current dollars (August 1986 basis), are plotted as a function of the quantity of SO₂ removed per year. In general, each point on a curve for a particular plant represents one of the generating units for that plant. The first point on each curve represents the generating unit(s) for which application of the particular technology is most cost-effective. The second point represents the next best cost-effective application, etc. until all of the units for which applying the technology is feasible are represented. This is the reason for the steadily increasing slope (in \$1000/ton) of each curve. Depending upon the emission reduction desired for a particular plant, an electric utility could use this approach to determine a minimum cost strategy for the plant.

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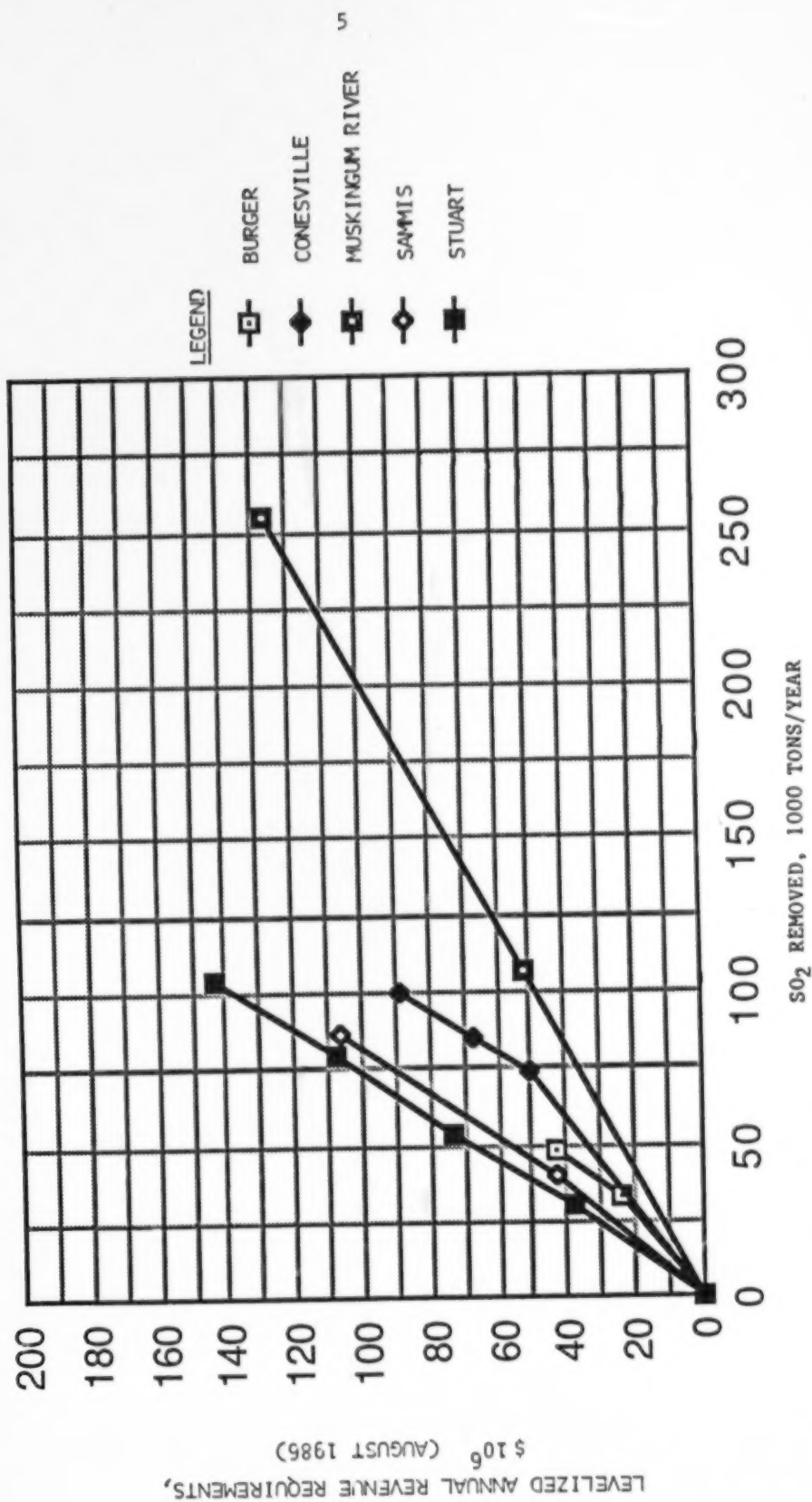


FIGURE 1. PERFORMANCE/COST ESTIMATES FOR SO₂ EMISSION REDUCTION VIA FLUE GAS DESULFURIZATION AT FIVE COAL-FIRED POWER PLANTS IN OHIO